Figure 26

16-VSB RECEIVER

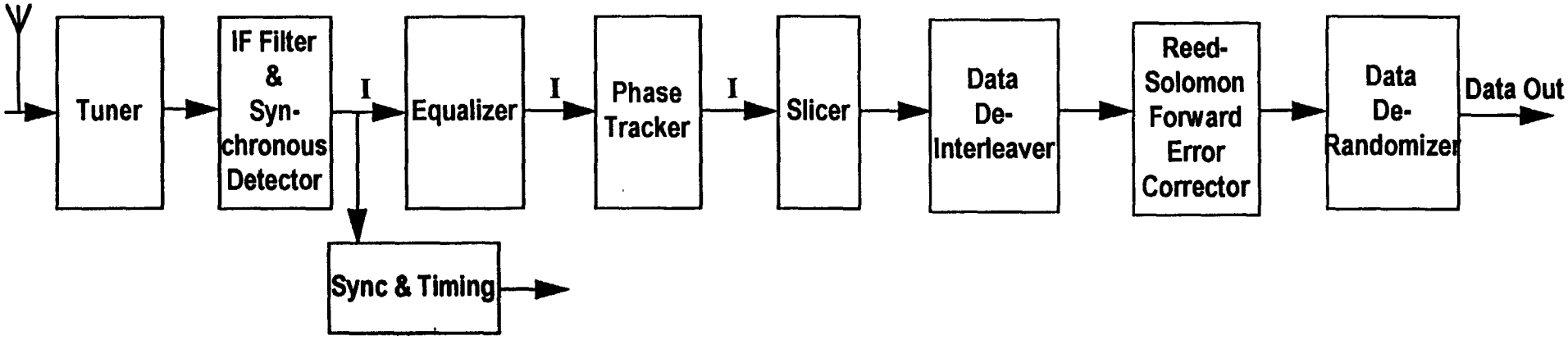


Figure 13

DATA SEGMENT SYNC

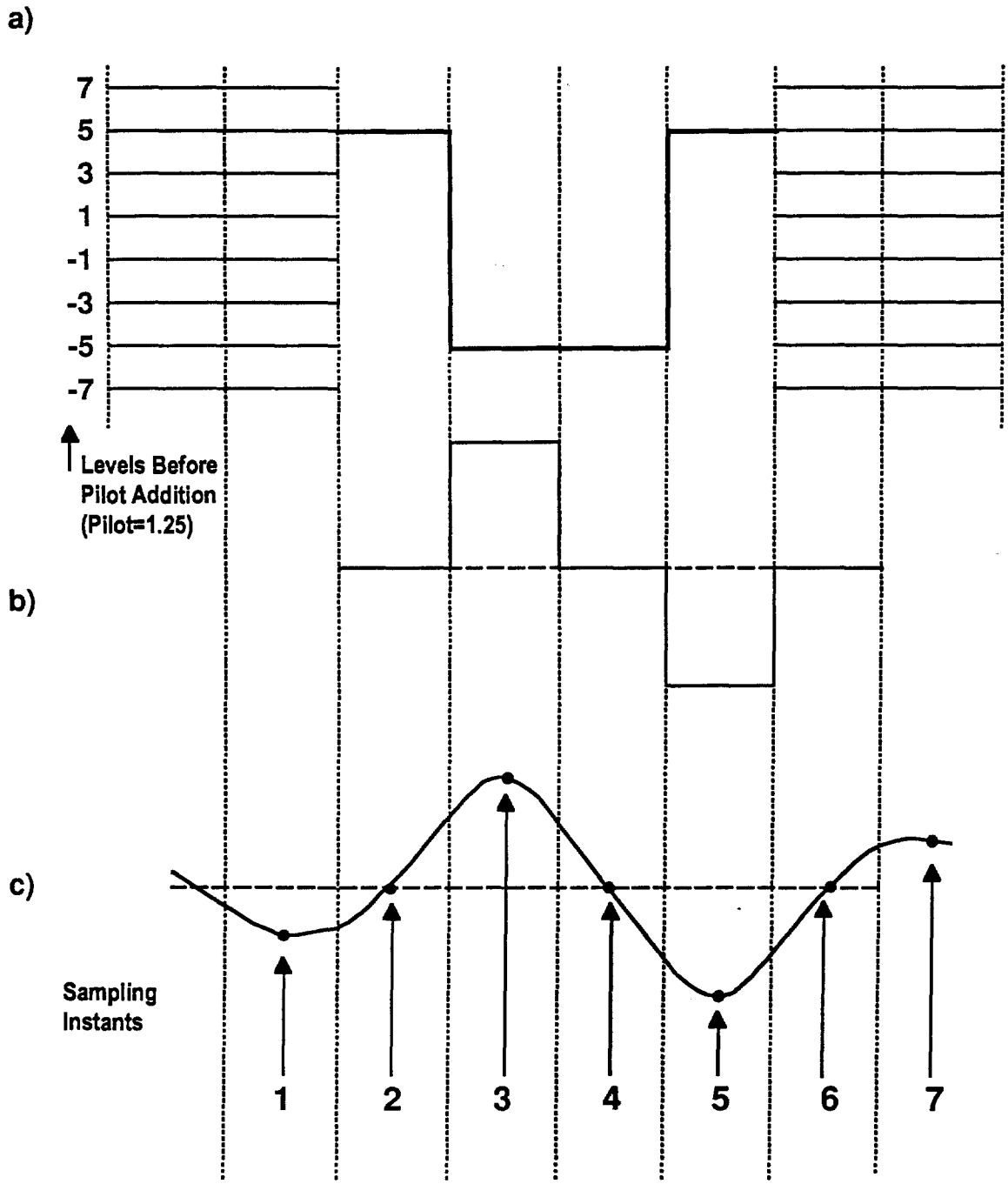


Figure 12

SEGMENT SYNC + SYMBOL CLOCK RECOVERY WITH AGC GENERATION

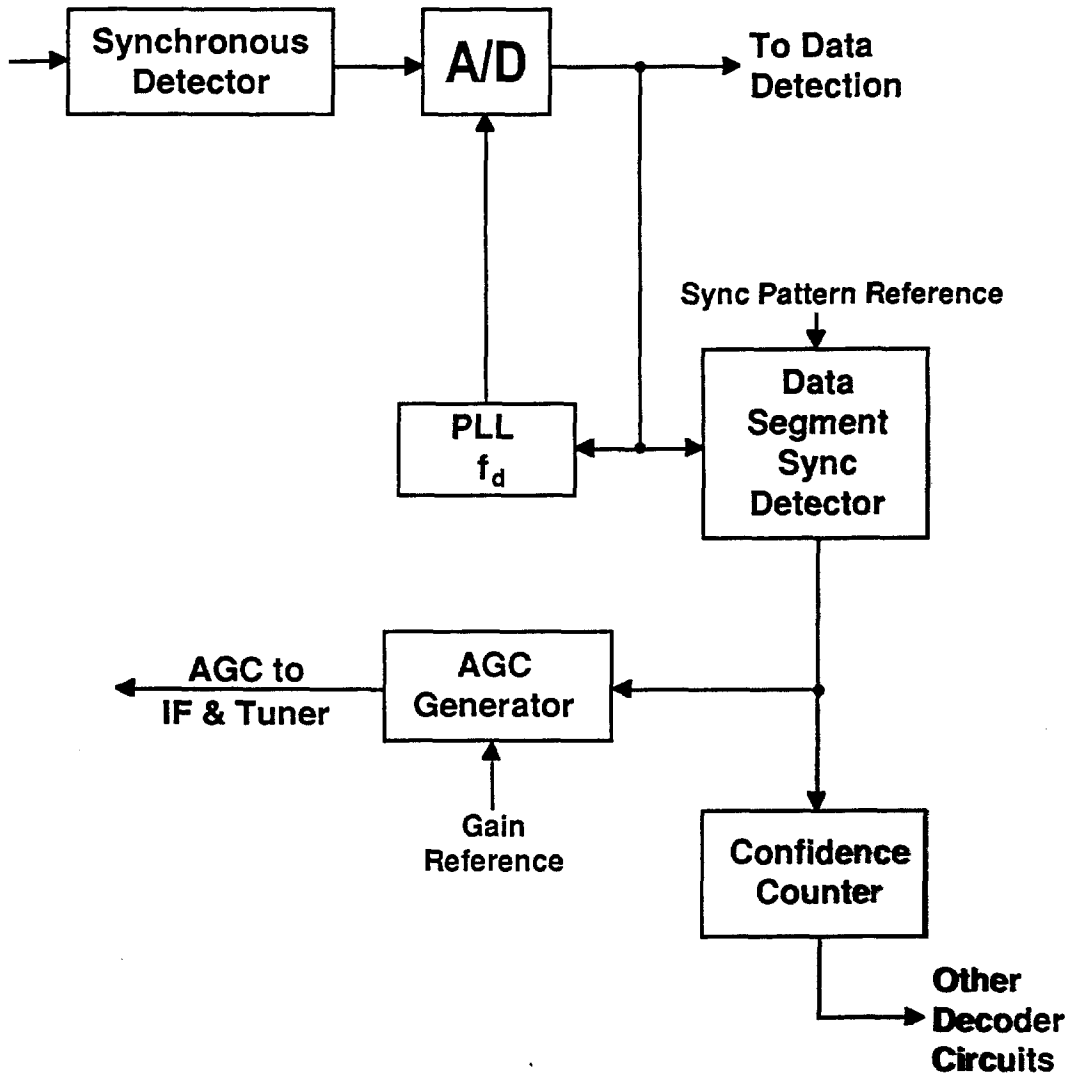
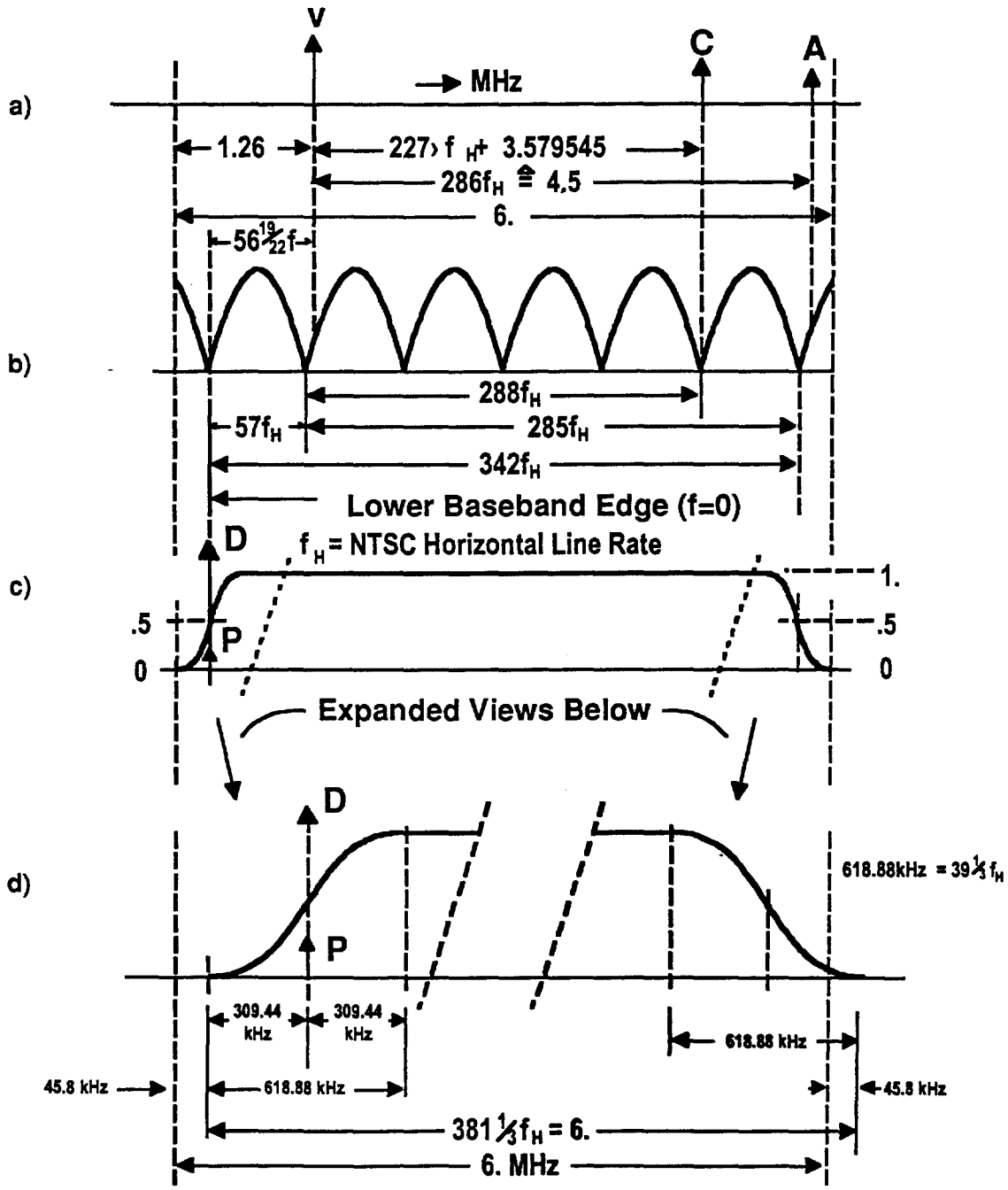


Figure 15

NTSC INTERFERENCE REJECTION FILTER SPECTRUM OCCUPANCY



Chapter 7

GRAND ALLIANCE SYSTEM SUMMARY

The following tables document features supported in the system description of the Grand Alliance HDTV specification. While the initial hardware prototype may not completely exercise all of the capabilities of the system standard, it is anticipated that future implementations will benefit from the flexibility provided by the standard.

SPECIFICATION TABLES

Video Parameter	Format 1	Format 2
Active Pixels	1280 (H) x 720 (V)	1920 (H) x 1080 (V)
Total Samples	1600 (H) x 787.5 (V)	2200 (H) x 1125 (V)
Frame Rate	60 Hz Progressive	60 Hz Interlaced / 30 Hz Progressive / 24 Hz Progressive
Chrominance Sampling	4:2:0	
Aspect Ratio	16:9	
Data Rate	Selected Fixed Rate, 10-45 Mbits / sec / or Variable	
Colorimetry	SMPTE 240 M	
Picture Coding Types	Intra Coded (I) / Predictive Coded (P) / Bidirectionally Predictive Coded (B)	
Video Refresh	I-Picture / Progressive	
Picture Structure	Frame / Field	
Coefficient Scan Pattern	Zig-Zag / Alternate Zig Zag	
DCT Modes	Frame	Frame / Field (60 Hz only)
Motion Compensation Modes	Frame	Frame / Field (60 Hz only) / Dual Prime (60 Hz only)
P-Frame Motion Vector Range	Horizontal: Unlimited by syntax Vertical: -128,+127.5	
B-Frame Motion Vector Range (forward and backward)	Horizontal: Unlimited by syntax Vertical: -128,+127.5	
Motion Vector Precision	1/2 Pixel	
DC Coefficient Precision	8 / 9/ 10 bits	
Rate Control	Modified TM5 with Forward Analyzer	
Film Mode Processing	Automated 3:2 Pulldown Detection and Coding	
Maximum VBV Buffer Size	8 Mbits	
Intra / Inter Quantization	Downloadable Matrices (Scene Dependent)	
VLC Coding	Separate Intra and Inter Runlength / Amplitude Codebooks	
Error Concealment	Motion Compensated Frame Holding (Slice Level)	

SPECIFICATION TABLES

Transmission Parameter	Terrestrial Mode	High Data Rate Cable Mode
Channel Bandwidth	6 MHz	6 MHz
Excess Bandwidth	11.5%	11.5%
Symbol Rate	10.76 MSPS	10.76 MSPS
Bits per Symbol	3	4
Trellis FEC	2/3 rate	None
Reed-Solomon FEC	T=10 (208, 188)	T=10 (208, 188)
Segment Length	836 Symbols	836 Symbols
Segment Sync	4 Symbols per segment	4 Symbols per segment
Frame Sync	1 per 313 segments	1 per 313 segments
Payload Data Rate	19.3 Mb/s	38.6 Mb/s
NTSC Co-Channel Rejection	NTSC Rejection Filter in receiver	N/A
Pilot Power Contribution	0.3 dB	0.3 dB
C/N Threshold	14.9 dB	28.3 dB

Audio Parameter	
Number of Channels	5.1
Audio Bandwidth	20-20KHz
Sampling Frequency	48 KHz
Dynamic Range	100 dB
Compressed Data Rate	384 KBits / sec.

Transport Parameter	
Multiplex Technique	MPEG-2 Systems Layer
Packet Size	188 Bytes
Packet Header	4 Bytes including sync
Number of services Conditional Access Error Handling Prioritization	 Payload scrambled on service basis 4-bit continuity counter 1 bit / packet
System Multiplex	Multiple program capability described in PSI stream

Chapter 8

PROTOTYPE HARDWARE IMPLEMENTATION

8.1 Overview

To demonstrate and verify the performance of the proposed standard, the member companies of the Grand Alliance, have combined their efforts to produce a hardware prototype for testing at the Advanced Television Test Center later this year. This prototype implementation will demonstrate excellent picture and sound quality, a flexible, packet-based transport, and transmission performance superior to previously tested systems. It is impractical, however, to incorporate all the flexibility and extensibility permitted by the standard into any one implementation. This chapter outlines the prototype design considerations and elements of the standard that will not be fully exercised in the initial implementation.

8.2 Video Compression Subsystem

The Video Compression subsystem implements a high level, main profile MPEG-2 compression algorithm. The MPEG-2 syntax offers an extremely powerful and flexible toolkit of compression techniques to cover a variety of multimedia communication capabilities. The prototype hardware will demonstrate excellent picture quality at the available bit rates, however it will not utilize all of the features available in the MPEG-2 syntax. Additionally, there are some features of the MPEG-2 algorithm that will be demonstrated with some restricted capabilities.

8.2.1 Picture Formats Supported:

The prototype hardware will be capable of compressing pictures in two input formats: 1920 x 1080 interlaced pictures at 60 fields per second and 1280 x 720 progressive pictures at 60 frames per second. The sequences will be coded in the format in which they are received. The compression decoder will be capable of recognizing, decoding and displaying pictures coded in either the progressive or interlace input format. Additionally, the decoder will have the capability to convert interlaced coded formats to a progressive display format. A similar capability will demonstrate conversion from progressive to interlaced formats.

The prototype will employ lookahead circuitry to detect and identify sequences that were originally sourced at 24 or 30 Hz progressive formats, and will take advantage of this redundancy by only coding the necessary frames. the hardware is not capable of directly receiving pictures whose input format and timebase are 24 frames per second. Information will be passed in the coded bitstream to allow the decoder to reconstruct and display the sequences at the appropriate input format.

8.2.2 Motion Compensation:

While the MPEG-2 syntax allows very extensive motion search range, the prototype will restrict its search range to +/- 128 pixels horizontally and +/- 32 pixels vertically for forward Predicted (P) frames, and +/- 64 pixels horizontally and +/- 32 pixels vertically in each temporal direction for Bi-directional predicted (B) frames. The motion vectors will be calculated and coded with 1/2 pixel accuracy. The prototype hardware will not implement concealment motion vectors.

The specification of the GA compression system includes the adaptive use of field, frame and dual prime prediction techniques for interlaced video. Since the dual prime technique is primarily useful for low-delay applications, it will not be included in the prototype hardware, in the interest of time.

8.2.3 Coding:

The prototype implements high-level, main profile of the MPEG-2 video coding standard. While the standard allows for variable bit-rate applications, the prototype will employ a selectable constant bit rate algorithm. The rate will be set through comminication with a computer console, and will allow the ability to show different allocations for video and data services.

Each video frame is coded in one of three modes: Intra-coding (MPEG I-picures), Predictive coding (MPEG P-pictures) or bi-directional predictive coding (MPEG B-pictures). The period of I-pictures (Group-of-pictures size, N) and the distance in number of frames between two anchor (I or P) pictures (known as M), can be programmed.

In the above mentioned mode of operation, I-pictures provide refresh. The codec will allow an alternate way of refreshing, which is achieved through progressive refresh. In this mode, parts of P-pictures (I-slices) are refreshed progressively. I-frames will be sent periodically when using progressive refresh mode to facilitate editing.

The chroma samples will be subsampled by a factor of two horizontally and vertically (4:2:0), relative to the luma sampling grid. The prototype will only use the standard coefficient scan pattern, not the alternate zig-zag. The DC DCT coefficients may be represented with a precision of either 8, 9, or 10 bits in the GA system. However the prototype will only support the use of 8 or 9 bits.

The GA specification includes the option of using field-structure pictures when processing interlaced video, however this option will not be used in the prototype. The maximum number of coded bits per frame will be 8 Mbits.

In addition to the features listed above, there are a number of extensions to the syntax supported in the GA system that are not implemented in the prototype. Pan and scan and picture display extensions will not be implemented. Also absent from the prototype will be spatial and temporal scalability extensions, that are not part of the main profile.

8.3 Audio Compression Subsystem

The prototype implementation of the audio compression subsystem is expected to include all features in the system description. Further details of the Audio compression prototype forthcoming.

8.4 Transport Subsystem

The transport subsystem is responsible for multiplexing the variety of services into a single bit stream for transmission. This subsystem also has the responsibility for managing and delivering synchronization information between the encoders and decoders. The GA transport system provides an extrordinary degree of flexibility. The transport bit stream could describe a large number of programs, each potentially consisting of a large number of individual services. This flexibility is intended for a broad scope of services and to allow for future growth.

The prototype hardware will implement all the MPEG-2 syntax elements that would allow this high degree of flexibility, but obviously will be limited in its ability to simultaneously exercise this flexibility. Nominally, the prototype will carry a single program of HDTV services. The prototype will, however, be capable of delivering two independent programs simultaneously. Each program can be comprised of up to five independent services (typically, one video, two audio, and two ancillary data services). The ancillary data services can be either synchronous or asynchronous with the video and audio services. For an 18.8 Mbps transmitted data stream, the transport decoder will be able to recognize all five of these services, but will simultaneously decode only three services (one video, one audio, and one data).

The capability to assign a higher priority to certain transport packets is a capability of the system that will not be used in the prototype hardware. The splice countdown function will also be absent in this first hardware implementation, however the system will allow for the discontinuity flag to signal the decoder of switching that has occured in the compressed bit stream domain.

To demonstrate the ability of the transport layer to support conditional access, the prototype will include the capability to scramble the payload of individual packets on a "service by service" basis. Packets whose payloads include adaptation headers, will not be scrambled. As a demonstration, this scrambling circuitry is based on the DES electronic codebook encryption algorithm. Key management for the decryption of these services can also be demonstrated as an example implementation.

8.5 Transmission Subsystem

The prototype implementation of the transmission subsystem is expected to include all features in the system description. Further details of the Transmission prototype will be forthcoming.

Chapter 9

PROJECTED PROTOTYPE PERFORMANCE

9.1 Projected Prototype Performance

The following tables detail the typical performance anticipated for the prototype implementation, when tested at the ATTC later this year. The tables identify tests that have been adopted by SS/WP-2 for system testing and evaluation. For each of these tests, a target specification has been entered. These target specifications have been developed by the Grand Alliance Specialist Group in cooperation with the ACATS Expert Groups, and detail the projected performance of the Grand Alliance prototype system. Comments may be entered to explain differences between the target specification and the measured value.

Transmission Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
CO-A/N	< 36.5 dB		
CO-N/A	< 3.5 dB		
CO-A/A	< 16.6 dB		
UP-A/N	< -12.5 dB		
UP-N/A	< -43 dB		
UP-A/A	< -37.5 dB		
LO-A/N	< -14.5 dB		
LO-N/A	< -41.5 dB		
LO-A/A	< -37.5 dB		
N-2 Taboo A/N	< -23.5 dB		
N+2 Taboo A/N	< -28.5 dB		
N+4 Taboo A/N	< -22.5 dB		
N+14 Taboo A/N	< -32.5 dB		
N+15 Taboo A/N	< -22.5 dB		
N-8 Taboo A/N	< -25.5 dB		
N-7 Taboo A/N	< -28.5 dB		
N+7 Taboo A/N	< -29.5 dB		
N+8 Taboo A/N	< -36.5 dB		
N-2 Taboo N/A	< -53 dB		
N-2 Taboo A/A	< -53 dB		
N+2 Taboo N/A	< -53 dB		
N+2 Taboo A/A	< -53 dB		
N-3 Taboo N/A	< -53 dB		
N-3 Taboo A/A	< -53 dB		
N+3 Taboo N/A	< -53 dB		
N+3 Taboo A/A	< -53 dB		
Random Noise in Presence of Multipath	< 3.5 dB		

Discrete Frequency Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
Discrete Frequencies (25)	< -39.5 dB adj. ch. < 12.75 dB in band		

Power Measurement Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
Peak/Average Power	< 6.95 dB		

Video — Objective Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
Static Resolution, Luma, H/V/D, 1080x1920	860/700/1110 lph		
Static Resolution , Chroma, H/V/D, 1080x1920	430/350/555 lph		
Dynamic Resolution, Camera, Luma, H/V/D, 1080x1920	690/560/890 lph		
Dynamic Resolution, Camera, Chroma, H/V/D, 1080x1920	345/280/445 lph		
Static Resolution, Luma, H/V/D, 1080x1440	650/700/960 lph		
Static Resolution , Chroma, H/V/D, 1080x1440	325/350/480 lph		
Dynamic Resolution, Camera, Luma, H/V/D, 1080x1440	520/560/760 lph		
Dynamic Resolution, Camera, Chroma, H/V/D, 1080x1440	260/280/380 lph		
Video-Audio Latency (1080-lines)	< 15 msec		
Video-Captioning Latency (1080-lines)	< 100 msec		
Static Resolution, Luma, H/V/D, 720x1280	580/650/870 lph		
Static Resolution , Chroma, H/V/D, 720x1280	290/325/435 lph		
Dynamic Resolution, Camera, Luma, H/V/D, 720x1280	460/520/690 lph		
Dynamic Resolution, Camera, Chroma, H/V/D, 720x1280	230/260/345 lph		
Video-Audio Latency (720-lines)	< 15 msec		
Video-Captioning Latency (720-lines)	< 100 msec		

Video Quality Tests — Non-Expert Observers			
Test	**Target Specification[1]**	**Measured Value**	**Comments**
Quality, Basic Material (1080-lines)	≤ 0.3 Grade below reference[2]		
Quality, Noise & Cuts (1080-lines)	≤ 1.0 Grade below reference[3]		
Quality, Graphics & NII (1080-lines)	None[4]		
Quality, 24 fps Film (1080-lines)	≤ 0.25 Grade below reference[2]		
Quality, Video/Auxiliary Data Tradeoff (1080-lines)	Video ≤1.0 Grade/Mb[3] Film ≤0.5 Grade/Mb[3]		
Quality, Receiver Conversion, 720-lines transmission, 1080-lines display	≤ 1.0 Grade		
Quality, Basic Material (720-lines)	≤ 0.3 Grade below reference[2]		
Quality, Noise & Cuts (720-lines)	≤ 1.0 Grade below reference[3]		
Quality, Graphics & NII (720-lines)	None[4]		
Quality, 24 fps Film (720-lines)	≤ 0.25 Grade below reference[2]		
Quality, Video/Auxiliary Data Tradeoff (720-lines)	Video≤1.0 Grade/Mb[3] Film ≤0.5 Grade/Mb[3]		
Quality, Receiver Conversion, 1080-lines transmission, 720-lines display	≤ 1.0 Grade		

[1] Grade is the average over all sequences tested, not the maximum.

[2] Comparison of the measured value with the target specification should be tempered by consideration of the selected test material.

[3] Quantitative data do not exist for the previous systems. This is a suggested target specification.

[4] Inasmuch as the material for this test is yet to be determined, and as the performance will depend on the selected source material, the target specification is yet to be determined.

Digital Specific Tests — Expert Observers			
Test	**Target Specification**	**Measured Value**	**Comments**
Threshold Characteristics for Random Noise - Video	< 15.6 dB		
Threshold Characteristics for Random Noise - Audio	< 15.6 dB		
Threshold Characteristics for Random Noise (Audio + Video)	Audio usable at or beyond video POU		
Free Form Viewing (1080-lines)	As good as or better than the best previous digital system[5]		
Quality, Scene Cuts (1080-lines)	As good as or better than the best previous digital system[5]		
Noise in Video Source (1080-lines)	As good as or better than the best previous digital system[5]		
Video Coder Overload (1080-lines)	As good as or better than the best previous digital system[5]		
Motion Compensation Overload (1080-lines)	As good as or better than the best previous digital system[5]		
Quality, Video/Auxiliary Data Tradeoff (1080-lines)	None[6]		
Concatenation Quality (1080-lines)	As good as or better than the best previous digital system[5]		
Free Form Viewing (720-lines)	As good as or better than the best previous digital system[5]		
Quality, Scene Cuts (720-lines)	As good as or better than the best previous digital system[5]		
Noise in Video Source (720-lines)	As good as or better than the best previous digital system[5]		
Motion Compensation Overload (720-lines)	As good as or better than the best previous digital system[5]		

[5] In testing the previous systems, qualitative observations were made by expert observers. No quantitative data were taken. The System Specific / Digital Specific Task Force should record quantitative comparisons with the reference and with the previous digital systems.

[6] No target specification; there is no present plan to gather quantitative data.

Digital Specific Tests — Expert Observers			
Test	**Target Specification**	**Measured Value**	**Comments**
Quality, Video/Auxiliary Data Tradeoff (720-lines)	None[6]		
Concatenation Quality (720-lines)	As good as or better than the best previous digital system[5]		

ATV Subjective Audio & Long Form Entertainment Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
ATV Multichannel Audio	Subjectively as good as or better than the Grand Alliance / Audio Experts Group tests		
Long Form Entertainment Program	EO&C, no noticeable impairments		

Audio — Objective Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
Frequency Response, Main Channels (10 Hz - 20 kHz)	± 0.25 dB		
Frequency Response, Subwoofer Channel (10 Hz - 120 Hz)	± 0.50 dB		
Dynamic Range	> 90 dB		
THD (at nominal test level)	< 0.1 %		
THD + N (at nominal test level)	< 0.1 %		
IM Distortion (at nominal test level)	< 0.1 %		

Interoperability & Packetization Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
Header/Descriptor Robustness	Demonstration only		
Switching between Compressed Data Streams	Demonstration only		
Simulation of ATM Network Transmission	Demonstration only		
Transport Interoperability with Computer Networks	Demonstration only		

Cable Television Tests			
Test	**Target Specification**	**Measured Value**	**Comments**
Composite Second Order Distortion	< 25 dB		
Composite Triple Beat Distortion	< 37 dB		
Phase Noise	< 81 dB		
Residual FM	> 6.5 kHz		
Fiber Optic Tests	> 4.5 %		
Channel Change / Channel Acquisition	< 0.7 sec		
Data Channel BER	< 15.6 dB		
Local Oscillator Instability	± 89 kHz		
Dynamic Multipath - Acquisition Time in the Presence of Multipath and Noise	< 0.75 sec		
Dynamic Multipath - Simulate Tower Sway	< 9.5 dB		
Burst Error Correction	> 169 sec @ 10 Hz > 1.05 kHz @ 20 sec		

Cable Television Tests with High Data Rate Transmission			
Test	**Target Specification**	**Measured Value**	**Comments**
Composite Second Order Distortion	< 38 dB		
Composite Triple Beat Distortion	< 49 dB		
Phase Noise	< 87 dB		
Residual FM	> 4.0 kHz		
Fiber Optic Tests	> 4.0 %		
Channel Change / Channel Acquisition	< 0.7 sec		
Data Channel BER	< 28.85 dB		
Local Oscillator Instability	± 89 kHz		
Dynamic Multipath - Acquisition Time in the Presence of Multipath and Noise	< 0.75 sec		
Burst Error Correction	> 129 sec @ 10 Hz > 1.45 kHz @ 20 sec		

Chapter 10

REFERENCED DOCUMENTS

The following documents are referenced for their detailed account of the syntatical elements of the Grand Alliance HDTV standard.

1) Generic Coding of Moving Pictures and Associated Audio
ISO/IEC 13818-1 Systems Committee Draft
November 1993

2) Generic Coding of Moving Pictures and Associated Audio
ISO/IEC 13818-2 Video Committee Draft
November 1993

3) AC-3 Multi-Channel Digital Audo Compression System Algorithm Description
Dolby Laboratories Revision 1.12
February 22, 1994

AC-3

MULTI-CHANNEL DIGITAL AUDIO COMPRESSION SYSTEM

Algorithm Description

February 22, 1994 Revision 1.12

Dolby Laboratories Information

 S92/9471

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1. INTRODUCTION

The objective of this document is to specify an algorithm for Dolby Laboratories' AC-3 multi-channel audio bitrate compression system. It is intended to be used as a guideline for software development, both high-level simulation and real-time.

2. BITSTREAM SYNTAX

2.1. Terminology and Definitions

2.1.1. Cross Reference Of Terminology Abbreviations

Abbreviation	Terminology
acmod	Audio Coding Mode
addbsi	Additional Bitstream Information
addbsie	Additional Bitstream Information Exists
addbsil	Additional Bitstream Information Length
audblk	Audio Block
audprodie	Audio Production Information Exists
audprodie2	Audio Production Information Exists, Ch2
auxbits	Auxiliary Data Bits
auxdata	Auxiliary Data Field
baie	Bit Allocation Information Exists
blksw	Block Switch Flag
bs	Bitstream
bsi	Bitstream Information
bsid	Bitstream Identification
bsmod	Bitstream Mode
chbwcod	Channel Bandwidth Code
chexpstr	Channel Exponent Strategy
chincpl	Channel In Coupling
chmant	Channel Mantissas
cmixlev	Center Mix Level
compr	Compression Gain Word
compr2	Compression Gain Word, Ch2
compre	Compression Gain Word Exists
compre2	Compression Gain Word Exists, Ch2
copyrightb	Copyright Bit
cplabsexp	Coupling Absolute Exponent
cplbegf	Coupling Begin Frequency Code

cplbndstrc	Coupling Band Structure
cplco	Coupling Coordinate
cplcoe	Coupling Coordinates Exist
cplcoexp	Coupling Coordinate Exponent
cpldeltba	Coupling Delta Bit Allocation
cpldeltbae	Coupling Delta Bit Allocation Exists
cpldeltlen	Coupling Delta Bit Allocation Length
cpldeltnseg	Coupling Delta Bit Allocation Number of Segments
cpldeltoffst	Coupling Delta Bit Allocation Offset
cplendf	Coupling End Frequency Code
cplexps	Coupling Exponents
cplexpstr	Coupling Exponent Strategy
cplfgaincod	Coupling Fast Gain Code
cplfleak	Coupling Fast Leak Initialization
cplfsnroffst	Coupling Fine SNR Offset
cplinu	Coupling In Use
cplleake	Coupling Leak Initialization Exists
cplmant	Coupling Mantissas
cplsleak	Coupling Slow Leak Initialization
cplstre	Coupling Strategy Exists
crc1	CRC - Cyclic Redundancy Check Word 1
crc2	CRC - Cyclic Redundancy Check Word 2
crcrsv	CRC Reserved Bit
csnroffst	Coarse SNR Offset
d15	D15 Exponent Coding Mode
d25	D25 Exponent Coding Mode
d45	D45 Exponent Coding Mode
dbpbcod	dB Per Bit Code
deltba	Channel Delta Bit Allocation
deltbae	Channel Delta Bit Allocation Exists
deltbaie	Delta Bit Allocation Information Exists
deltlen	Channel Delta Bit Allocation Length
deltnseg	Channel Delta Bit Allocation Number of Segments
deltoffst	Channel Delta Bit Allocation Offset
dialnorm	Dialog Normalization Word
dialnorm2	Dialog Normalization Word, Ch2
dithflag	Dither Flag
dsurmod	Dolby Surround Mode
dynrng	Dynamic Range Gain Word
dynrng2	Dynamic Range Gain Word, Ch2
dynrnge	Dynamic Range Gain Word Exists
dynrnge2	Dynamic Range Gain Word Exists, Ch2
exps	Channel Exponents
fdcycod	Fast Decay Code
fgaincod	Channel Fast Gain Code